detailed tracings packed in the ship's hold were lost. Mr. Hussey's discussion shows that "January 1915 was dull and overcast, only 7 per cent. of the observations recording a clear blue sky, 71 per cent. being completely overcast." The clearest weather occurred in winter, when the sky was cloudless for nearly half the time. Some interesting results are likely to accrue when the meteorological records are worked up in detail and co-ordinated with other observations from South Atlantic and South American stations. "Temperatures on the whole were fairly high, though a sudden unexpected drop in February, after a series of heavy north-easterly gales, caused the ship to be frozen in, and effectually put an end to any hopes of landing that year. The lowest temperature experienced was in July, when 35° Fahr., *i.e.* 67° below freezing, was reached."

For determining the position in drifting pack ice, Mr. James found the theodolite a more generally useful instrument than the sextant, as the ice-floes were found quite steady in really thick pack ice, and the theodolite can be set up and levelled as well as on dry land. Mr. James shows that "the *Endurance* was carried by the ice-drift well to the west of the Weddell Sea, towards the position of the supposed Morrell Land, so that the accurate determination of longitude became a matter of moment in view of the controversy as to the existence of this land." The existence or non-existence of Morrell Land, however, has yet to be investigated more thoroughly, in spite of the assurance of Sir Ernest Shackleton and others that it does not exist. If it is a low *"cluster of islands,"* it would not have been seen at all; the party may have drifted on the floe to the west of it.

Sir Ernest Shackleton's appendix on the lists of provisions and gear in the McMurdo Sound huts is most useful and important for future expeditions.

Finally, the drift party reached Elephant Island, which was one of the places the Admiralty had planned to search. But several landings were made there a century ago, and Sir Ernest Shackleton's expedition is not the first to land there, as he quite excusably supposes. The voyage to South Georgia was a wonderful piece of seamanship and endurance, and Sir Ernest Shackleton has again shown that he can lead men. The story of the *Aurora* with MacIntosh and Stenhouse is another disaster. Spencer Smith unfortunately died while doing land work, which included, however, successful depôt laying, under MacIntosh. The absence of scurvy, on the Weddell Sea side, shows what is possible if fresh meat is mainly adhered to.

MacIntosh and Hayward lost their lives in a blizzard while attempting to cross from Hut Point to Cape Evans on thin ice, and were blown out to sea.

Capt. Stenhouse, of the *Aurora*, handled that vessel with marked ability during her ten months' drift beset in the ice. No mention is made of any systematic scientific work having been accomplished by the Ross Sea party. W. S. B.

TELEPHONING BY LIGHT.

TELEPHONY by means of light is a particular case of wireless telephony. It differs from what is generally understood as wireless telephony in no essential respect. In both cases electromagnetic waves are used, but whereas in ordinary wireless the waves are very long, in the case of light they are very short. As a consequence, telephony by light is easily directed by means of lenses or mirrors, and constitutes a secret means of communication—a state of affairs not yet attained in what is popularly known as Marconi wireless transmission. At the same time, the use of light imposes definite limits on the possible range of light telephony. An uninterrupted straight line is essential between the sending and receiving stations, and the extreme range is therefore determined by the curvature of the earth and the altitudes of the stations.

The transmission of speech by light is rendered possible by the well-known property possessed by selenium (and certain other substances) of changing its electrical conductivity when subjected to varying illumination. Selenium thus acts as a sort of electric valve controlled by light. It is capable of responding to some extent to light fluctuations of comparatively high frequency. If a selenium cell is connected in simple circuit with a battery and a telephone receiver—as shown in Fig. 1—fluctuating currents are obtained possessing the same characteristics as the variations of the incident light, and if the latter are of audible frequency the corresponding sounds are heard in the receiver. The problem of light telephony is thus reduced to the production of a beam of light fluctuating in intensity in accordance with the vibrations constituting the speech sounds.

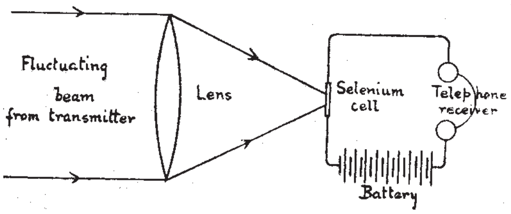

FIG. 1.

The construction of the first transmitter of this kind was due to Graham Bell, who in 1880 succeeded in transmitting speech by means of a beam of sunlight over a distance of about 200 yards. Telephony by light is, indeed, almost as old as ordinary telephony, and Graham Bell was the inventor of both. It is difficult to account for the difference in the rate of development of the two systems; the fact remains that ordinary telephony is now in common use, whilst telephony by light is still a novelty. Graham Bell's first photophone —as it was called—consisted of a large diaphragm, silvered so as to become a mirror. Upon this mirror a beam of light was projected and thence reflected to the distant selenium receiver. Speech sounds, falling on the diaphragm, set it in vibration, thus causing its curvature to change. The result was that the reflected beam became alternately more and less divergent, so that the amount of light incident on the selenium executed fluctuations of the original frequency and amplitude, and the speech sounds were reproduced in the telephone receiver. Other forms of transmitter are also described by Graham Bell, but it is doubtful whether they were actually successful in practice.

Little further work on the subject appears to have been done until about 1900, when Ernst Ruhmer carried out for the German Government a long series of experiments. He approached the problem from a different point of view. Instead of seeking to impose fluctuations of intensity on a beam of light from a constant source, as Graham Bell had done, he arranged to control the brightness of the source itself by means of the vibrations of speech. The sensitive or speaking arc was already known, and Ruhmer improved it for the purpose of light telephony. Briefly, the principle amounts to this. The current in an electric arc controls the brightness of the arc. Variations of current produce variations of brightness. By means of a transformer, the fluctuations of current in a microphone actuated by speech can be introduced into the arc circuit, and thus produce changes of brilliancy corresponding to the speech vibrations. Ruhmer succeeded in perfecting this system, and claims to have communicated speech over several miles by projecting the beam from the fluctuating arc, by means of a searchlight reflector, on to a distant selenium cell.

This method suffers from several disadvantages, of which the chief is that it is limited to the arc as a source of light, and rules out the use of that much more efficient source—the sun. It is difficult also to maintain the arc in the necessary sensitive condition; it requires continual adjustment. It was these considerations which caused the present writer, in working for the British Admiralty on the subject in 1916, to revert to the general method adopted by Graham Bell—namely, to interrupt the light after it had left the source. The essential point which had to be borne in mind was that the vibrations which it is possible to impart by speech to a diaphragm are of very small amplitude—a few thousandths of an inch only. In order to use these vibrations for producing large fluctuations of intensity in a beam of light, magnification is necessary. In the transmitter about to be described, it will be seen that the magnification is optical. There are many possible variations of the apparatus, but the essential features are shown in Fig. 2. Speech sounds enter the trumpet and fall upon the diaphragm of a gramophone sound-box. To the lever of this sound-box, at the place which the needle ordinarily occupies, is attached a small galvanometer mirror. The vibrations of the diaphragm cause this mirror to execute small *angular* oscillations about an axis perpendicular to the plane of the diagram. Light from a suitable source, such as an arc, or, it may be, the sun, is focussed by means of the first lens upon the vibrating mirror; thence it is reflected through the second lens. The focus of this lens coincides with the vibrating mirror, so that the emergent beam is a parallel one.

A grid consisting of equal and parallel strips alternately opaque and transparent is placed close to the first lens, and a second equal grid near the second or projecting lens. The result is that the light from each point of the source is split up into segments indicated by the unshaded portions, and the extent to which the light penetrates the second grid depends on the momentary position of the vibrating mirror. As shown in Fig. 2, about 50 per cent. of the maximum is being projected, but evidently if the mirror turns through a small angle in a clockwise direction the reflected segments will turn also, and the light penetrating the second grid will increase; a counter-clockwise movement of the vibrating mirror will, on the other hand, diminish the light projected.

Thus, in so far as the mirror copies the vibrations of speech, and provided that the amplitude is not allowed to be greater than that corresponding to the width of one space of the grids, a fluctuating beam of the desired character is obtained. It may be projected on to the receiving apparatus shown in Fig. 1 and used for the transmission of speech. By making the width of the grid spaces small in comparison with the distances between the grids and the vibrating mirror, adequate control of the light intensity is secured, even though the movements of the diaphragm are so small. It is, in fact, easy to reach the stage when the grids must be made no narrower, otherwise the amplitude of movement of the segments of light is excessive, and the frequency of interruption becomes doubled or even trebled—to the detriment of articulation in the received speech. It should be pointed out that the diagram shows only the light proceeding from a single point of the source. Actually, every source is finite in size, and in order to provide for this it is necessary to use as the vibrating mirror a *concave* reflector, the radius of curvature of which is equal to the distance between the grids and the mirror. A real image of the first grid is thus obtained on the second, and this image moves in the manner of a shutter when the mirror oscillates.

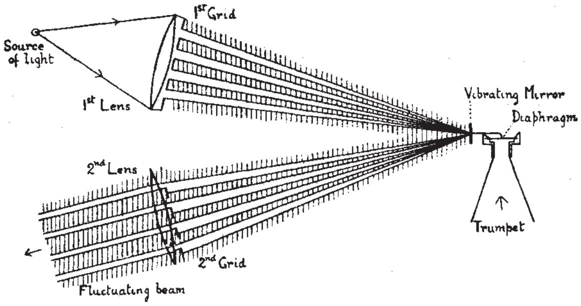

FIG. 2.

Fig. 3 is a photograph of a transmitter arranged for use with sunlight, and mounted so that it can be directed as desired. The lenses are 6 in. in diameter, and the range with sunlight, when a 6-in. collecting lens is also used, is about 8 miles. It is impossible at present to say what the ultimate limit of range may be. It depends on the apertures of the projecting and receiving optical systems, the brilliancy of the source, and the extent to which amplification by means of thermionic valves may be possible in reception. The selenium cells which the author has used were made by Dr. Fournier d'Albe, and they have given very satisfactory results, the articulation of the speech heard being extraordinarily perfect. Their special sensitivity to red light perhaps accounts for the fact that a small amount of mist between the sending and receiving stations has been found not to interfere greatly with transmission.

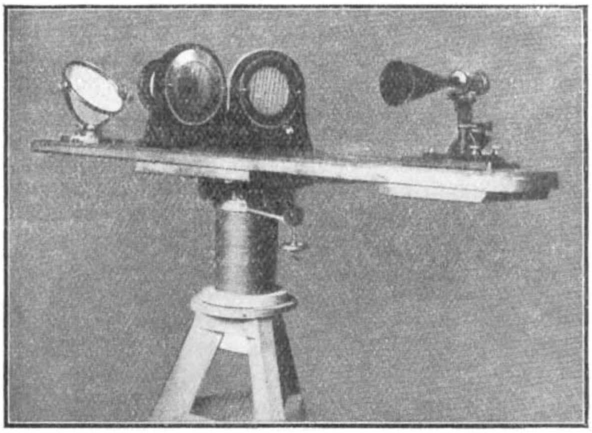

FIG. 3.

In this short article it has not been possible to give more than a brief description of essential points. Fuller details both of the photophone and of its application to the photographic recording and reproduction of sounds may be found in the Proceedings of the Physical Society of London.[1]

A. O. RANKINE.

AUSTRALIAN RAINFALL AND WHEAT YIELD.

UNTIL large schemes for the conservation of water supply with a view to irrigation have been carried out, the incidence of drought at frequent intervals is bound to have a great influence, not only on the sheep runs of the Australian Commonwealth, but also on its wheat crop. It is perhaps surprising that the relation between rainfall and wheat yield should be to a great extent directly traceable, when we consider to how many indirect influences the yield is exposed. The seed varies in such obvious characteristics as size and hardness, as well as in power of resistance to disease, partly modified by the conditions under which the crop producing the seed has been raised. There is, moreover, no constancy in the soil, which differs from place to place in composition, in aspect, elevation, and slope, from farm to farm in the amount and choice of fertilising agents, and from district to district in the dates of weather changes and precipitation. There is possible loss by barrenness of seed, by ground pests before germination, by vermin during growth, by storms, birds, insects, and disease when the grain is in the ear, and much may be shaken out when ripe if the harvest weather be very hot and dry.

In spite, however, of all these disturbing factors we find from the latest official publication on the subject strong evidence of direct correlation between the wheat yield per acre and the rainfall of the previous winter. For South Australia and the Northern Territory the correlation coefficient works out at 0·61, with a probable error of 0·07. It must be admitted that the data are far from being homogeneous, comparatively few of the stations yielding figures for the whole period. The publication is entitled "Results of Rainfall Observations made in South Australia and the Northern Territory, including all available annual rainfall totals from 829 stations for all years of record up to 1917, with maps and diagrams, also appendices presenting monthly and yearly Meteorological Elements for Adelaide and Darwin" (Green, Acting Government Printer, Melbourne, 1918), and is the fourth of a series. Previous volumes dealt with the Eastern Provinces (Queensland, New South Wales, and Victoria), and two more are contemplated to complete the set by including Western Australia and Tasmania.

There is a wealth of detail contained in the four hundred or so pages, to say nothing of the seasonal maps and diagrams. The territory covered is large, more than 900,000 square miles, and the annual rainfall varies from 4·07 in. at Mulloorina in the centre to 61·37 in. at Darwin in the Northern Territory and 45·91 in. at Stirling West in South Australia. The mean annual rainfall for the Northern Territory (four-sevenths of the whole) is 19·52 in. (thirty-seven years' average), the extremes being 30·28 in. in 1904 and 12·20 in. in 1905. For South Australia the mean is 9·39 in., and the extremes, curiously enough also in consecutive years, 15 in. in 1889 and 5·88 in. in 1888. Of forty-seven counties with a long record, twenty-eight had their driest year in 1914, and twenty-five their wettest in 1916. In quite a large number of districts, accordingly, the wheat yield per acre was lowest in 1914 and highest in 1916. The most conspicuous dry periods were 1895 to 1902 and 1911 to 1915. It may be noted that rainfall was deficient at Greenwich also for each year of the first of these periods, but not for the second.

Conditions at Adelaide, which has the longest meteorological record in the district, are very different from those at Greenwich, but there is some similarity in the rainfall. The wettest day at Adelaide in seventy-seven years was March 5, 1878, with 3·50 in., the number of daily falls

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[1] Proc. Phys. Soc., vol. xxxi., p. 242, and paper read December 12, 1919.